FINAL DRAINAGE REPORT

TOWN OF BOWERS BEACH
KENT COUNTY, DELAWARE

Prepared For
Delaware Coastal Program
Delaware Department of Natural Resources and Environmental Control

Prepared By
KCI Technologies, Inc.
KCI Project 27100612

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INTRODUCTION

The purpose of this report is to recommend drainage improvements and provide conceptual designs for the top three ranked drainage problems in the Town of Bowers Beach. Existing drainage problems were identified in the *Preliminary Drainage Report*; and the *Ranking Report* prioritized specific problem areas for The Town of Bowers Beach, located in South Murderkill Hundred, Kent County, Delaware.

The Town of Bowers Beach has historically been a small residential waterman's village located on a neck of habitable land lying between the Delaware Bay on the east, the Saint Jones River on the North, and the Murderkill River on the South. A major shift in demographics occurred over the last ten years, reflecting a trend from an economic foundation based on fishing and agricultural industries to a primarily residential community. This trend is expected to continue (*Town of Bowers Draft Comprehensive Plan*, February 2009). As with many coastal towns on the east coast of the United States, Bowers Beach faces worsening flooding and coastal hazards.

The Town of Bowers Beach and the Delaware Coastal Programs (DCP), Delaware Department of Natural Resources and Environmental Control, have been working together to address the Town's drainage issues. After several years of coordination, the Town and DCP have completed an initial flooding and coastal hazards vulnerability assessment and have commenced the phase of developing mitigation strategies. KCI Technologies, Inc. (KCI) was contracted by DCP to provide technical assistance in the development of these strategies.

This report offers a summary of the past vulnerability assessment activities conducted to date by the Town and DCP, as well as recent activities conducted by KCI, including the following:

- Accumulating additional field collected data,
- Creating a Geographic Information System (GIS) support system and topographic model,
- Prioritizing and ranking the Town's drainage problems, and
- Recommending conceptual designs for improvements to the Town's drainage system to help mitigate the identified problems.

The goal is for the information provided in this report, in conjunction with the necessary efforts by the Town and DCP, to serve as a basis for establishing avenues to implement the recommended improvements to reduce the impact of flooding to the Town of Bowers Beach.

FLOODING AND COASTAL HAZARD VULNERABILITY ASSESSMENT

Bowers Beach is a typical coastal community currently experiencing a number of coastal hazard related problems, including episodic storm drainage, coastal erosion, and nuisance street flooding. The United States Army Corps of Engineers (1991) calculated an erosion rate of two feet/year for Bowers Beach. Flooding occurs frequently due to the following (*Coastal Storm Damage 1923–1974,* 1977):

(1) The proximity to rivers,
(2) The mosquito ditch system, which provides inland access to floodwaters that would otherwise be confined;
(3) Beach erosion that lowers the height of the beach; and
(4) Strong winds that 'pile up' water inland, holding it there until wind direction changes.

As previously mentioned, the Town and DCP have been working together for the past couple years to address the Town's drainage issues. The following is a summary of coordination efforts and documents related to the drainage issues in Bowers Beach:

- Bowers Beach Comprehensive Plan – February 2009
- DNREC Comments on Bowers Beach Comprehensive Plan – March 2009
- Bowers Beach Coastal Hazards Resiliency Planning Meeting – April 18, 2009
- Development of a Coastal Hazards Resiliency Action Plan for Bowers Beach, Delaware – April 2009
- Coastal Hazards Characterization Workshop – June 13, 2009
- Coastal Hazards Characterization Workshop: Summary Document – August 2009
- Management Plan for the Delaware Bay Beaches: Final Report – March 2010
- Bowers Beach Drainage Study Kick-Off Meeting – July 27, 2010
- KCI Storm System Inventory/Inspection – August/September 2010
- KCI Survey Data – October 2010

The Bowers Beach Coastal Hazards Characterization Workshop held on June 13, 2009 was a first step towards developing a Coastal Hazards Resiliency Action Plan for the Town. This workshop brought together Bowers Beach residents, town officials and DCP, with the goal of obtaining residents' views on specific flooding and coastal storm events. More importantly, this workshop allowed DCP to solicit priority concerns and begin the task of developing mitigation strategies. A Summary Document (August 2009) for the workshop concluded that the Town of Bowers Beach is greatly vulnerable to the impacts of coastal hazards of all degrees. In addition, DCP and the Town realize that strategies developed to mitigate current flooding and coastal hazards should take into consideration future risks as well, such as potential climate change and sea level rise.

Based on the responses provided by workshop participants and the identification of potential risks through discussion and survey results, there are four main causes of the Town's current drainage issues:

(1) Spring Tide Flooding,
(2) Nor'easter Flooding,
(3) Extreme Storm Event Flooding, and,
(4) Potential Flooding from Future Risks, such as Climate Change and Sea Level Rise.

Views and opinions from the workshop indicated that the effects from Nor'easters were the residents' primary concern. Therefore, in the development of Coastal Hazards Resiliency Action Plan strategies, priority should be given to actions that mitigate against potential losses from Nor'easter related impacts. Doing so also has the potential benefit to alleviate a major portion of tidal flooding issues as well.

KCI began providing technical assistance on the Bowers Beach Drainage Investigation in July 2010. KCI became educated on the extent of flooding and coastal hazards in the Town by utilizing the following:

- Summary of the Coastal Hazards Characterization Workshop, developed by DCP, as described above.
- Records of drainage complaints for Bowers Beach from local, county and state government offices.
- Specific location of drainage and flooding issues as identified by Town landowners and residents.
- Inventory and Inspection of the existing open and closed storm drain system conducted by KCI.
- Spot elevation data at critical points within the Town as surveyed by KCI.
- Historic tidal data as recorded by regional tidal stations, as well as site photographs that were captured during extreme flooding events.

KCI developed a GIS support system geodatabase that combines a majority of the information and data into one database. Spatial data utilized in support of the project was consolidated and organized in an ESRI file format. A simple geodatabase model was created to store and access the Bowers Beach field data collected by Global Positioning System (GPS), survey, and site photographs. All GIS data elements were projected to the NAD83 Delaware State Plane coordinate system.

In addition, KCI created a topographic model utilizing Light Detection and Ranging (LIDAR) topographic data and supplemental field survey data to match the localized observations with various historic tidal event elevations and general tidal elevations, as classified and recorded by the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS).

Appendix A of this report includes the GIS database created by KCI for the Bowers Beach Drainage Investigation.

Appendix B of this report (Figure 1) has the geographical location of all listed drainage issues.

Appendix C of this report contains construction cost estimates for the three conceptual designs.

Appendix D of this report contains the conceptual design plans for the top three ranked problem areas. These designs include plan and profile information as well as specific details.

FLOODING AND DRAINAGE ISSUES

The three types of coastal storms and flooding discussed at the Coastal Hazards Characterization Workshop include Spring Tide Flooding, Nor'easters and Extreme Storms (i.e., tropical storms and hurricanes), as discussed below.

1. Spring Tide Flooding

Spring tides are especially strong tides that occur during the full and new moon phases. Spring tides are known to have higher tides and lower low tides due to the combined gravitational pull of the sun and the moon. The Spring Tide Flooding areas of concern have been categorized into S1 through S7 and, if possible, are geographically depicted on Figure 1 in **Appendix B**. Each area of concern has been geographically labeled on Figure 1.

S1: Flooding of N. Bayshore Drive and portions of Main Street

S2: Murderkill River flooding in the vicinity of Hubbard, Cooper and Murderkill Avenues; Flooding amplified by degraded seawall at end of Hubbard Avenue.

S3: Flooding of portions of Davidson St. and Bowers Beach Rd.; Water depths noted at least 1 ft. deep.

S4: N. Bayshore Dr. and between S. Bayshore and S. Flack do not drain as rapidly; Manual pumping to remove water required.

S5: Flooding of low-lying structures, particularly along low-lying Hubbard Avenue.

S6: Boat docks and ramps along Murderkill River are overtopped.

S7: Increased mosquito populations.

2. Nor'easter Flooding

Nor'easters are extratropical storms which can occur at any time of the year but are typically experienced during the fall and winter months. High winds, pounding surf and heavy rain or snow conditions are typical of Nor'easters. The Nor'easter Flooding areas of concern have been categorized into N1 through N6 and, if possible, are geographically depicted on Figure 1 in **Appendix B**.

N1: Flood waters are much more intensive and can remain for several days to a week; Depths noted between 3 and 4 ft.; Evacuation routes blocked.

N2: Salt water intrusion causing well water contamination and fish kills.

N3: Property damage including inundation of vehicles and structures.

N4: Significant erosion to beach and dune systems.

N5: Local Businesses have to close for 3-4 weeks.

N6: Emergency Services are limited during and after storms.

Extreme Storm Event Flooding

Extreme storm events include hurricanes, tropical and extratropical storms, and exceptionally strong Nor'easters. The Extreme Storm Event Flooding areas of concern have been categorized into E1 and E2.

E1: No possible evacuation; Homes destroyed; All natural barriers washed away

E2: Dune system is insufficient

The inadequate dune system allows for extensive damage from wave action and storm surge. The final report titled *Management Plan for Delaware Bay Beaches* (DNREC, PBS&J March 2010), recommends strategic fill replacement for 5 and 10-year scenarios.

3. Potential Flooding from Future Events

Predicted future risks include climate change and sea level rise. The model was evaluated under three conditions of sea level rise as indicated in the report titled *Climate Change and the Delaware Estuary* (June 2010). These three scenarios are sea level rises of 0.5 meters, 1.0 meters, and 1.5 meters, respectively, for the Delaware Bay.

FLOODING AND DRAINAGE DEFICIENCES

Based on extensive field investigation and observations, survey, topographic modeling and tidal and storm event research, the following deficiencies were determined to be the major contributing factors to the flooding and drainage issues of the Town of Bowers Beach, Delaware:

D-1. Inefficient hydraulic performance of drainage conveyance due to clogging from sediment, fill, vegetation, and general lack of maintenance.

D-2. Inefficient hydraulic design and alignment (vertical and horizontal) of drainage conveyance systems.

D-3. The erosion of the sand dunes located along the Delaware Bay coastline.

D-4. Malfunctioning or absence of tide control valves.

D-5. Low-lying roadway elevations.

D-6. Ineffectiveness or absence of seawall, low-lying bulkhead and boat ramp area elevations.

RELATIONSHIPS BETWEEN ISSUES AND DRAINAGE DEFICIENCIES

The following table summarizes the flooding and drainage issues and the corresponding deficiencies as listed in the previous sections of this report:

		FLOODING AND DRAINAGE DEFICIENCES					
		D-1	**D-2**	**D-3**	**D-4**	**D-5**	**D-6**
FLOODING AND DRAINAGE ISSUES	**S1**	X	X		X	X	X
	S2	X	X		X	X	X
	S3		X			X	X
	S4	X	X		X		
	S5	X	X		X	X	X
	S6						X
	S7	X	X				
	N1	X	X		X	X	X
	N2					X	X
	N3		X	X	X	X	X
	N4			X			
	N5	X	X	X	X	X	X
	N6					X	X
	E1			X		X	X
	E2			X			

SUMMARY OF RELATIONSHIPS BETWEEN ISSUES AND DEFICIENCIES

Clogged Conveyance inlets, pipes and ditches (D-1) is a causative factor for over 70% of the Spring Tide issues, and 33% of the Nor'easter issues. The vertical elevation of the conveyance systems along with inefficient geometric layout (D-2) contributes to approximately 86% of the Spring Tide issues, as well as 50% of the Nor'easter issues. The erosion of the town's dune system (D-3) contributes to none of the Spring Tide issues, but partially accounts for 50% of the Nor'easter issues and 100% of the Extreme Storm Event issues. The malfunctioning of the existing tide control valve and the absence of these valves at other key locations (D-4) is a causative factor for 57% of the Spring Tide issues as well as 50% of the Nor'easter issues. The Town's low-lying roadway elevations (D-5) contribute to 57% of the Spring Tide issues, 83% of the Nor'easter issues, and 50% of the Extreme Storm Event issues. The ineffectiveness of the seawall along the Murderkill River and the absence of a functioning seawall at other key locations (D-6) is a causative factor for 71% of the Spring Tide issues, 83% of the Nor'easter issues, and 50% of the Extreme Storm Event issues.

The Spring Tide flooding issues are generally caused by the inundation of tidewater into the Town's conveyance system in combination with the low elevation of roadways and the absence of appropriate seawalls and tide control valves. The clogged conveyance systems reduce the Town's ability to dewater in a timely manner, resulting in prolonged periods of flooding and flooding associated with typical rain events.

The Nor'easter flooding issues are generally caused by the tidewater encroaching overland due to the low-lying nature of the Town's roadways in combination with the lack of a substantial seawall design. The erosion of the Town's dune system also contributes to the Nor'easter issues. Flood waters remain high due to the inability of the Town's conveyance system to drain properly, because of clogging associated with sediment and vegetation.

Extreme Event flooding issues are caused by the erosion of the Town's dune system, as well as overland flooding of the Town's low-lying roadways in conjunction with the lack of an adequate seawall design.

RANKING CRITERIA AND MEETING

A meeting was held on December 10, 2010 with the project's steering committee to review and discuss the findings of the *Preliminary Drainage Report*, and to develop a ranking system based on an established ranking criteria to prioritize the identified drainage problems. The following impacts were considered:

A Emergency Services and Access
B. Public Health and Safety
C. Disruption to Local Businesses
D. Property Damage
E. Environmental Impact
F Costs associated with correction of Drainage Problems
G Timeframe associated with the Implementation of Drainage Corrections

Sea Level Rise

Sea Level Rise was discussed as an inescapable scenario that will plague the Town of Bowers Beach in the future. Possible solutions to Sea Level Rise discussed included the annexation of lands to the west and the possibility of pumping flood waters and other engineered solutions, including the raising of roadways.

Ranking

Discussions at the meeting resulted in the ranking based on specific, geographical corrections that could be implemented, which will have an immediate, positive effect on the drainage system and nuisance flooding. Longer-term issues, including maintenance, the replenishment of the dune system and the raising of roadways such as Bowers Beach Road, will require a more timely and costly approach to achieving the desired results, and have therefore been omitted from the ranking list at this time. It was discussed and agreed upon that the more short-term solutions be implemented in a way that will positively affect entire watersheds or drainage areas, working

from the bottom up in an effort to minimize expenditure and maximize results on the drainage systems in specific areas. These areas were prioritized based on input from the steering committee and the feasibility of the designs.

RANKING SUMMARY

The flooding issues listed below are ranked in order from highest priority to lowest priority, in terms of applying geographically specific engineered corrections:

1. Flooding of Hubbard Avenue (S2, S5, S4, S7)

The flooding associated with Hubbard Avenue affects a substantial portion of the area draining to the Murderkill River, mostly due to the condition of the storm drain system and malfunctioning tide control valve in this area. The correction of this condition will have an immediate positive impact on the entire drainage area contributing to this location.

2. Flooding of area at north end of Town (S1, S4, S7)

The drainage conveyance at the northern end of this area has been blocked and filled in, affecting the drainage performance of the system all the way upstream. A cross-culvert under North Flack Avenue has been installed allowing flood waters to intrude into the drainage system along this road. While the raising of roadway (North Flack) is likely the only way to reduce overland flooding, the correction of the drainage in this location will have an immediate positive impact on the entire drainage area contributing to this location for nuisance flooding events.

3. Flooding as a result of the parking lot runoff and deficient conveyance alignment between Hubbard Avenue and South Flack Avenue (S2, S5, S4, S7)

The addition of this large portion of runoff to the storm drain under Hubbard Avenue amplifies the flooding issues of the system. The existing drainage alignment is extremely inefficient and contributes to slow drainage. The re-routing of this system will have an immediate positive impact on the drainage system under Hubbard Avenue, and therefore the entire contributing drainage area.

4. Flooding of Wyatt Street (S3)

The low-lying area of Wyatt Street is regularly flooded by overland encroachment from the existing ditch located to the west. While the low-lying nature of the roadway allows overland flooding, the lack of a tide-control valve at this location allows tidewater intrusion into the system, reducing its capacity during rain events. Correcting this condition will have an immediate positive impact in this area.

GENERAL RECOMMENDATIONS

A combination of both structural and non-structural measures are recommended and listed below to help mitigate the drainage and flooding problems in the Town of Bowers Beach.

R-1. Tideflex Valves

Due to the low-lying nature of the town and its drainage collection system, KCI recommends that additional tideflex valves be placed at strategic locations to minimize the effect of tidal intrusion into the storm drain collection system. It is recommended that these valves be located within appropriately sized storm drain box-type structures for access and maintenance purposes, and also to reduce the likelihood of long-term defects to the valves as a result of perpendicular water currents, UV rays and other weather conditions. These structures as well as the structures placed upstream of the valves should be constructed with adequate sumps of 2-3 feet in depth to collect sediment in an effort to also reduce the likelihood of valve defects due to accumulated sedimentation and clogging underneath the valve. Trash racks should be provided at both upstream and downstream entrances and exits to the valve to reduce the likelihood of clogging from both upstream drainage as well as tidal intrusion. The implementation of General recommendation R-1 will help to address Spring Tide Flooding Issues S1, S2, S4, and S5.

R-2. Sea Walls

Portions of the Town's seawall system along the Murderkill River are in significant need of repair and have substantial breach locations, specifically at the end of Hubbard Avenue. KCI recommends the replenishment of the seawalls at this and other breach locations to reduce the likelihood of overland tidal intrusion. The implementation of General Recommendation R-2 will help to address Spring Tide Flooding Issues S2, S3, S5, and S-6; and Nor'easter Flooding Issues N1, N2, N3, N5, and N6; and Extreme Storm Event Flooding Issue E1.

R-3. Re-alignment of Drainage Conveyance

KCI recommends regrading specific portions of drainage swale and realignment of the storm drain to better distribute large flow rates, specifically in the areas associated with the large parking lot runoff and the storm drain and outfall located under Hubbard Avenue, as well as the area in the vicinity of North Flack and North Bayshore Avenues. The implementation of General Recommendation R-3 will help to address Spring Tide Drainage Issues S1, S2, S4, S-5, and S-7; and Nor'easter Flooding Issue N1.

R-4. System Maintenance

KCI recommends that a maintenance plan be implemented to keep the storm drain collection system functioning properly and free of accumulated sediment, vegetation, and debris. Initial cleaning and removal of sediment and clogging vegetation should be performed immediately, with periodic inspection and flushing of the system thereafter. KCI recommends the annual inspection of the system, and maintenance measures, including flushing and vegetation removal (as required) of the system be performed on the system as required based on the findings of the

annual inspection. The implementation of General Recommendation R-4 will help to address Spring Tide Drainage Issues S1, S2, S3, S4, and S5; and Nor'easter Flooding Issue N1.

R-5. Replenishment of Dune System

KCI recommends that the existing dune system be replenished and maintained to the elevations and design as recommended in the report titled *Management Plan for Delaware Bay Beaches*. The existing breach location at 172 Bayshore Drive should also be addressed. The implementation of General Recommendation R-5 will help to address Nor'easter Flooding Issues N3 and N4, as well as Extreme Storm Event Flooding Issues E1 and E2.

R-6. Raising of Roadways

As a long term solution, the raising of roads, specifically in the low-lying area of Bowers Beach Boulevard, should be considered to help address concerns with emergency access and the disruption of businesses. The implementation of General Recommendation R-6 will help to address Spring Tide Flooding Issues S1, S3, and S5; Nor'easter Flooding Issues N1, N2, N3, N5, and N6; as well as Extreme Storm Event Flooding Issue E1. The raising of roadways is also recommended in the planning for Sea Level Rise.

CONCEPTUAL DESIGNS AND ANTICIPATED IMPROVEMENTS

Based on the ranking criteria and the results of the steering committee meeting held on December 10, 2010, three conceptual designs have been prepared to mitigate the three highest-priority drainage problem areas. These designs are located in Appendix C. The three Concept Designs have been modeled to quantify the extent of improvements anticipated as a result of their implementation. Quantification of restored stormwater volume (previous volume lost due to existing conditions) has been calculated for two of the three designs utilizing the topographic flood model and stormwater conveyance intrusion model. The improvements of the third design are quantified by reduction of stormwater runoff rates utilizing the rational method Q=CIA. The designs and their anticipated improvements have been described below, as well as the relationship of the improvements to various tidal flooding events, including sea level rise. Below is a chart summarizing the flood elevations (NAVD 1988) of the modeled flooding events.

Flood/Tidal Condition or Event	Current Sea Level	0.5M Sea Level Rise	1.0M Sea Level Rise	1.5M Sea Level Rise
Mother's Day Storm of 2008	6.9	8.54	10.18	11.82
Recorded Spring Tide Extreme (3/13/2010)	4.5	6.14	7.78	9.42
Predicted Spring Tide Extreme (4/28/2010)	3.4	5.04	6.68	8.32
Mean High Water(MHW) Elevation	2.0	3.64	5.28	6.92

1. Hubbard Avenue Storm Drain and Seawall

A conceptual design has been prepared for the area in the vicinity of the Hubbard Avenue storm drain outfall. The design consists of the reconstruction of the seawall and storm drain system in this area to accommodate a new tideflex valve to protect the system from tidewater intrusion. The improvement will provide flood management for Mean High Water Elevation, the Predicted Spring Tide Extreme Elevation (2010), and the Mean High Water Elevation Associated with a 0.5M Sea Level Rise. Flood Elevations above 4.1(NAVD 1988) result in overland flood waters encroaching from multiple locations, including the low-lying boat ramps located to the east of Hubbard Avenue, bypassing the improvement design. Therefore, the volume retained at flood elevation 4.1(NAVD 1988) as determined by the flood model represents the maximum restored volume as a result of the proposed improvement per the concept design. At Flood Elevation 4.1, the improvement will restore approximately 77,650 c.f. of volume, which includes 74,250 c.f. of storage in low-lying areas and ditches as well as 3,400 c.f. of storage within the storm drain conveyance pipes affected by this design.

2. North Flack Avenue and North Bayshore Drive Drainage and Outfall

A conceptual design has been prepared for the area in the vicinity of the North Flack Avenue and North Bayshore Drive storm drain conveyance and proposed outfall. The design consists of the proposed re-alignment and reconstruction of the conveyance system and the construction of a new outfall location at the Delaware Bay shoreline near the mouth of the Saint Jones River to improve drainage and allow the low-lying marsh area to the west to drain through the system. The outfall design considers an alternate location requiring an agreement with the owner(s) of parcel SM01-115.13-01-03.00 and the design also accommodates a tideflex valve to protect the entire system from tidewater intrusion. The improvement will provide flood management for Mean High Water Elevation, the Predicted Spring Tide Extreme Elevation (2010), and the Mean High Water Elevation Associated with a 0.5M Sea Level Rise. Flooding above elevation 3.9 (NAVD 1988) results in flood waters encroaching overtop of North Flack Avenue, bypassing the location of the improvement design. Therefore, the volume retained at Flood Elevation 3.9 (NAVD 1988) as determined by the flood model represents the maximum retained volume as a result of the proposed improvement per the concept design. At Flood Elevation 3.9, the improvement will restore approximately 123,767 c.f. of volume, which includes 123,012 c.f. of storage in low-lying areas and ditches as well as 755 c.f. of storage within the storm drain conveyance pipes affected by this design.

3. Parking Area storm drain re-alignment and new outfall

A conceptual design has been prepared for the area in the vicinity of the large parking area located between South Flack Avenue and Clifton Cubbage Drive. The design consists of the proposed re-alignment and reconstruction of the conveyance system and the construction of a new outfall location at the Murderkill River requiring an agreement with the owner(s) of Parcels SM01-115.17-02-22.00 and SM01-115.17-02-62.00. The design consists of the construction of a new storm drain that will be sized to accommodate a tideflex valve. The design will significantly reduce the large amount of flow currently affecting the Hubbard Avenue storm

drain system. Volume restoration capacity for this area has been accounted for and quantified by Concept Design #1. The reduction of runoff to the end of Hubbard Street as a result of Concept Design #3 has been calculated and is as follows:

The existing 10-year peak discharge rate(rational method) to the outfall at the end of Hubbard Street is currently 89 c.f.s. +/-. The proposed 10-year peak discharge rate (rational method) to the outfall at the end of Hubbard Street as a result of Concept Design #3 is 59 c.f.s. +/-, resulting in a 34% decrease in flow based on the concept design. Rational Equation Calculations including drainage areas have been included in the concept design plans attached to this report.

CONCLUSIONS

The Town of Bowers Beach, located along the eastern coast of Delaware in Kent County, is facing flooding and coastal hazards typical of many coastal towns. The Town sits in a low-lying area between the Delaware Bay on the east, the Saint Jones River on the North, and the Murderkill River on the South. In addition to the low-lying elevation, many drainage deficiencies exist and without correction, the Town of Bowers Beach will continue to face worsening flooding and coastal hazards. The Town of Bowers Beach, the Delaware Coastal Programs (DCP), Delaware Department of Natural Resources and Environmental Control and KCI Technologies, Inc. (KCI) have been working together to address the Town's drainage issues.

The drainage issues and deficiencies as outlined in the *Preliminary Drainage Report* were presented at a meeting with the project's steering committee on December 10, 2010. The discussions held at the meeting resulted in confirmation of the findings as outlined in the *Preliminary Drainage Report*, as well as a clearly designated ranking of the town's drainage issues and possible solutions to correcting these issues.

General recommendations have been provided including the addition of tideflex valves, the reconstruction of deficient portions of the existing seawall, the re-alignment of the Town's conveyance systems, the raising of roadways, the replenishment of the Town's dune system along the Delaware Bay, and the development and implementation of a maintenance plan to keep the Town's storm drain system properly functioning.

Three conceptual designs have been prepared for the top three highest priority areas based on the project steering committee meeting held on December 10, 2010. These three designs have been prepared with construction cost estimates. The three designs provided are intended to mitigate the drainage problems associated with Hubbard Avenue, the large parking lot located between South Flack Avenue and Clifton Cubbage Drive, and the area located at the north end of North Flack Avenue and North Bayshore Drive.

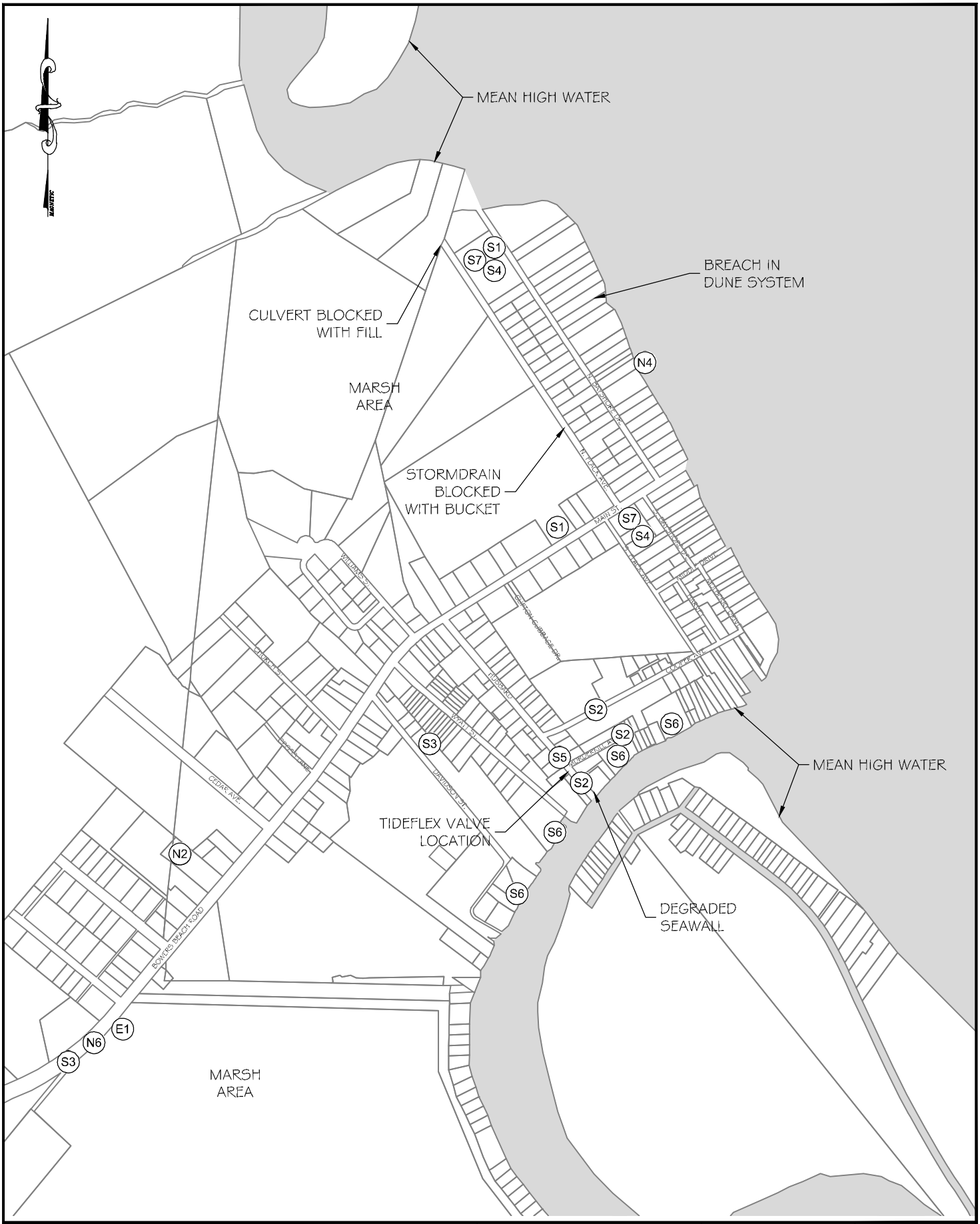
The purpose of this report is to provide the necessary research, investigation results, recommendations and designs to serve as the basis for establishing avenues for the Town of Bowers Beach and the DCP to pursue the necessary steps towards the construction and implementation of the recommendations and the mitigation of the Town's drainage problems.

APPENDIX A

ARCGIS GEODATABASE CD

APPENDIX B

FIGURE 1



KCI TECHNOLOGIES, INC.
ENGINEERS - PLANNERS - SURVEYORS
1352 MARROWS ROAD - SUITE 100 - NEWARK, DELAWARE 19711
PHONE: (302) 731-9176 FAX: (302) 731-7807 Website: www.kci.com

BOWERS BEACH
LOCATION MAP

DATE: 11/5/10	SCALE: 1" = 600'
Drafting: CEM	Check: BCM
KCI JOB# 27100612	FIGURE 1

APPENDIX C

COST ESTIMATES

TOWN OF BOWERS BEACH, DE
CONCEPTUAL DESIGN 1
ENGINEERING COST ESTIMATE

Date: 1/25/2011

SUBBASE COURSES	UNITS	QUANTITY	UNIT PRICE	TOTAL
8" Crusher run (CR-6)/467 base	SY	216	$20.66	$4,462.56
BITUMINOUS PAVEMENTS	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Wearing Course - 3" thick	SY	270	$17.00	$4,590.00
Pavement removal	SY	270	$11.80	$3,186.00
REINFORCED CIRCULAR CONCRETE PIPE (CLASS 3)*	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
24"	LF	243	$75.52	$18,351.36
36" flared end section	EACH		$1,050.00	$0.00
* Class 4: add 20%				
RCCPA: Deduct $3/LF				
STRUCTURES	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Standard Single Grate Inlet	EACH	2	$5,310.00	$10,620.00
Standard Double Grate Inlet	EACH	1	$7,080.00	$7,080.00
24" Tideflex 35-1	EACH	1	$9,722.00	$9,722.00
Marine Bulkhead	LF	35	$750.00	$26,250.00
EROSION AND SEDIMENT CONTROL	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
E&S - General	Acre	0.1	$23,120.00	$2,312.00

Subtotal	**$86,573.92**
MOT 20%	**$17,314.78**
Total	**$103,888.70**

TOWN OF BOWERS BEACH, DE
CONCEPTUAL DESIGN 2
ENGINEERING COST ESTIMATE

Date: 1/25/2011

SUBBASE COURSES	UNITS	QUANTITY	UNIT PRICE	TOTAL
8" Crusher run (CR-6)/467 base	SY	1062	$20.66	$21,940.92
BITUMINOUS PAVEMENTS	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Wearing Course - 3" thick	SY	1328	$17.00	$22,576.00
Pavement removal	SY	1328	$11.80	$15,670.40
REINFORCED CIRCULAR CONCRETE PIPE (CLASS 3)*	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
15"	LF	34	$53.00	$1,802.00
24"	LF	192	$75.52	$14,499.84
36"	LF	542	$95.00	$51,490.00
36" flared end section	EACH	1	$1,238.00	$1,238.00
* Class 4: add 20%				
RCCPA: Deduct $3/LF				
STRUCTURES	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Standard Double Grate Inlet	EACH	2	$7,080.00	$14,160.00
Standard Storm Drain Manhole	EACH	6	$5,310.00	$31,860.00
36" Tideflex 35-1	EACH	2	$16,400.00	$32,800.00
HEADWALLS	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
TYPE B ROUND				
60"	EACH	1	$6,400.00	$6,400.00
EROSION AND SEDIMENT CONTROL	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
E&S - General	Acre	0.2	$23,120.00	$4,624.00
			Subtotal	**$219,061.16**
			MOT 20%	**$43,812.23**
			Total	**$262,873.39**

TOWN OF BOWERS BEACH, DE
CONCEPTUAL DESIGN 3
ENGINEERING COST ESTIMATE

Date: 1/25/2011

SUBBASE COURSES	UNITS	QUANTITY	UNIT PRICE	TOTAL
8" Crusher run (CR-6)/467 base	SY	1062	$20.66	$21,940.92
BITUMINOUS PAVEMENTS	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Wearing Course - 3" thick	SY	1328	$17.00	$22,576.00
Pavement removal	SY	1328	$11.80	$15,670.40
REINFORCED CIRCULAR CONCRETE PIPE (CLASS 3)*	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
24"	LF	585	$75.52	$44,179.20
* Class 4: add 20%				
RCCPA: Deduct $3/LF				
STRUCTURES	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
Standard Single Grate Inlet	EACH	2	$5,310.00	$10,620.00
Standard Double Grate Inlet	EACH	1	$7,080.00	$7,080.00
Standard Storm Drain Manhole	EACH	1	$5,310.00	$5,310.00
36" Tideflex 35-1	EACH	1	$16,400.00	$16,400.00
HEADWALLS	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
TYPE B ROUND				
60"	EACH	2	$7,552.00	$15,104.00
EROSION AND SEDIMENT CONTROL	**UNITS**	**QUANTITY**	**UNIT PRICE**	**TOTAL**
E&S - General	Acre	0.25	$23,120.00	$5,780.00
			Subtotal	**$164,660.52**
			MOT 20%	**$32,932.10**
			Total	**$197,592.62**

APPENDIX D

CONCEPTUAL DESIGNS